

ION MICROPROBE MEASUREMENTS OF COMET DUST AND IMPLCATIONS FOR MODELS OF OXYGEN ISOTOPE HETEROGENEITY IN THE SOLAR SYSTEM. C. J. Snead¹, K. D. McKeegan¹, L.P. Keller and S. Messenger² ¹Dept. of Planetary, and Space Sciences, UCLA, Los Angeles, CA, 90095-1567, USA, ²Robert M. Walker Laboratory for Space Science, Code KR, ARES, NASA/JSC, Houston, TX 77058.

Introduction: The oxygen isotopic compositions of anhydrous minerals in carbonaceous chondrites reflect mixing between a ¹⁶O-rich and a ^{17,18}O-rich reservoir. The UV photodissociation of CO (i.e. self-shielding) has been proposed as a mass-independent mechanism for producing these isotopically distinct reservoirs. Self-shielding models predict the composition for the CO gas reservoir to be ¹⁶O-rich, and that the accreting primordial dust was in isotopic equilibrium with the gaseous reservoir [1, 2]. Self-shielding also predicts that cometary water, presumed to represent the ^{17,18}O-rich reservoir, should be enriched in ¹⁷O and ¹⁸O, with compositions of 200 -1000‰, and that the interaction with this ^{17,18}O-rich H₂O reservoir altered the compositions of the primordial dust toward planetary values. The bulk composition of the solar nebula, which may be an approximation to the ¹⁶O-rich gaseous reservoir, has been constrained by the Genesis results [3]. However, material representing the ¹⁷O,¹⁸O-rich end-member is rare [4], and dust representing the original accreting primordial dust has been challenging to conclusively identify in current collections.

Anhydrous dust from comets, which accreted in the distal cold regions of the nebula at temperatures below ~30K, may provide the best opportunity to measure the oxygen isotope composition of primordial dust. Chondritic porous interplanetary dust particles (CP-IDPs) have been suggested as having cometary origins [5]; however, until direct comparisons with dust from a known comet parent body were made, link between CP-IDPs and comets remained circumstantial. Oxygen isotope analyses of particles from comet 81P/Wild 2 collected by NASA's Stardust mission have revealed surprising similarities to minerals in carbonaceous chondrites which have been interpreted as evidence for large scale radial migration of dust components from the inner solar nebula to the accretion regions of Jupiter-family comets [6]. These studies have been largely focused on the coarse-grained terminal particles extracted from aerogel collectors; hypervelocity capture into aerogel resulted in fine-grained material that was melted and intimately mixed with the SiO₂ capture medium. Hypervelocity impacts into Al foils surrounding the aerogel tiles produced impact craters that captured material from the impactor without significant oxygen contamination, allowing for analysis of both

the coarse and fine-grained components of the Wild 2 dust.

To date, no particles with definitive hydrated mineralogy have been observed in Stardust samples, though this may be a result of alteration due to hypervelocity capture. High-carbon hydrated CS-IDPs have been suggested as resulting from the aqueous alteration of CP-IDPs [7], and may retain evidence for interaction with ^{17,18}O-enriched "cometary" water predicted by CO self-shielding. Here we present results of oxygen isotope measurements of twelve Stardust foil craters and four C-rich hydrated IDPs [8, 9], and discuss implications for models of oxygen isotope heterogeneity in the early solar system.

Analytical Methods: The oxygen isotope compositions of twelve craters from Stardust foil collectors were measured via Secondary Ion Mass Spectrometry (SIMS) at UCLA using a 20KeV, 0.5 nA 15μm rastered or 30μm defocused cesium primary beam. Secondary ions were counted via multicollection using two electron multipliers and one Faraday cup. A mass resolving power >6000 was used to separate the interfering ¹⁶OH⁻ peak from the ¹⁷O⁻ signal. Wild 2 crater measurements were normalized to San Carlos olivine that had been powdered and fired at foil targets at 6 km/s to produce standard crater residues.

Hydrated interplanetary dust particles were measured using a 20KeV, 3nA focused cesium primary beam or a 20KeV, 0.5nA 15μm rastered cesium primary beam. Entrance and exit slits were configured to achieve a mass resolving power of >7000 to separate the ¹⁶OH⁻ peak from the ¹⁷O⁻ signal. Secondary ions were counted via multicollection using two electron multipliers and a Faraday cup. San Carlos olivine and Afrique magnetite standards were used to correct for instrumental mass fractionation and matrix effects.

Results – Wild 2 Craters: Oxygen isotope compositions for Wild 2 dust, as measured in the residues retained in impact craters, show an average oxygen isotope composition similar to planetary compositions, with most Δ¹⁷O values within ±10‰ of planetary values. Morphological comparisons to lab-produced hypervelocity impacts show that Stardust craters analyzed in this study represent both the coarse and fine-grained components of Wild 2 dust. The O-isotope compositions of the crater residues are broadly consistent with those reported for Stardust terminal particles [10-12], though craters appear slightly offset by several permil/amu. However, Stardust crater O-isotope compositions are indistinguishable from those

reported for anhydrous interplanetary dust particles [13, 14], suggesting a slight compositional difference between the fine-grained dust (which was preferentially destroyed during aerogel capture) and the coarse-grained crystalline terminal particles.

Results – Hydrated IDPs Oxygen isotope analyses of four carbon-rich hydrated interplanetary dust particles reveal a range of positive $\Delta^{17}\text{O}$ values, from $+1.8 \pm 2.2\text{‰}$ to $+37.4 \pm 3.8\text{‰}$ (2 s.e.). Particles with the largest $\Delta^{17}\text{O}$ values are associated with Fe phases, and may reflect assimilation via oxidation of Fe metal by $^{17,18}\text{O}$ -enriched H_2O . Evidence for this $^{17,18}\text{O}$ -rich reservoir have been previously reported in Fe phases [4].

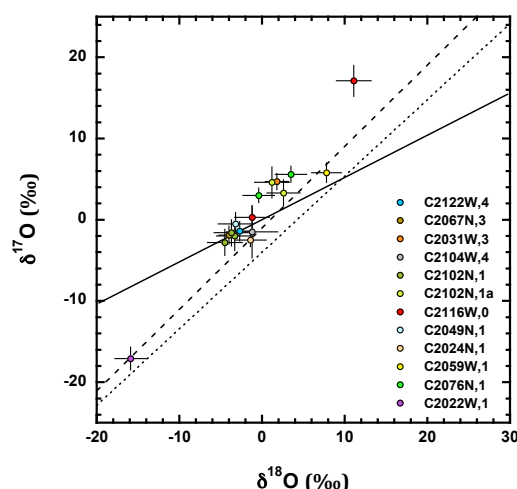


Fig. 1: Oxygen isotope compositions of twelve Stardust crater residues. Error bars are 2 s.e.

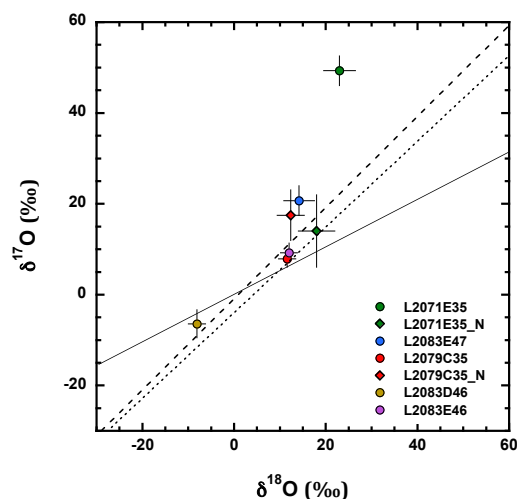


Fig. 2: Oxygen isotope compositions of four hydrated IDPs and one anhydrous IDP. Error bars are 2 s.e. NanoSIMS measurements from thin sections of 2 IDPs are indicated by (_N)

Discussion: Oxygen isotope compositions have been used as a tool for classification of meteorite groups. The similarity in the O-isotope compositions of CP-IDPs and Wild 2 dust supports the identification of short-period comets being the parent bodies of CP-IDPs [15-18]. The compositions of the hydrated IDPs show evidence of interaction with a $^{17,18}\text{O}$ -rich reservoir that was produced by CO self-shielding; yet measurements of the anhydrous Wild 2 dust reveal compositions similar to planetary materials. O-isotope compositions of the coarse and fine-grained components of Wild 2 dust should be equally well-preserved in craters. If ^{16}O -rich primordial dust was present in Wild 2 material, but was preferentially destroyed via aerogel capture, crater residues should be ^{16}O -rich relative to terminal particles. The absence of ^{16}O -rich dust may represent the complete pollution of comet accreting regions by processed inner solar system material, or it could indicate that the average initial primordial dust compositions have been largely retained in planetary solids. If the latter interpretation is correct, CO self-shielding minimally affected the oxygen isotope compositions of most of the solar system's silicate dust, with ^{16}O -rich CAIs and chondrules representing a minor component of condensates that exchanged with the isotopically light CO gas inherited by the Sun.

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